BIRD'S-EYE VIEWS.

BY DR. ELLIOTT COUES, U. S. A.

(Concluded from page 513.)

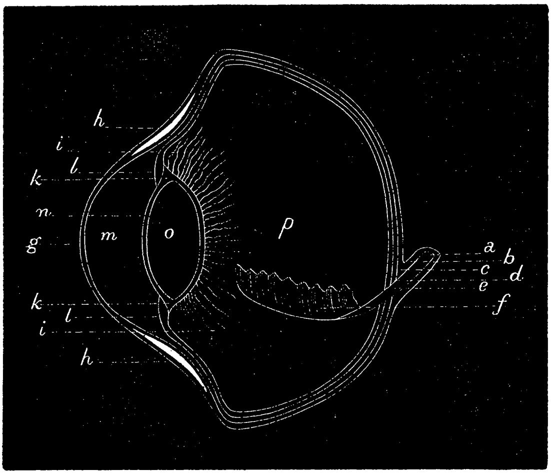
In our last "View" we saw all the appendages of a bird's eye; and now we come to look at the eye itself. "Eyeball" and "globe of the eye" are very convenient terms, constantly in our mouths; but they are not strictly accurate ones. Probably there are no perfectly spherical eyes. In our own species, the eye is made up of a segment of a large sphere, representing about five-sixths of its superficies; the other sixth is a smaller segment of a small sphere, joined in front to the former. Most mammal's eyes are not very different in this respect from our own. Bird's eyes are much further removed from perfect sphericity. The greater part of the ball is saucer-shaped,—almost discoidal; and there is a very convex prominence, more or less hemispherical in shape, in front. The whole eye may be likened to an acorn of one of those oaks that bear a fruit with a heavy broad shallow cup, and short blunt kernel, or to a thick old-fashioned watch with a very convex crystal.

This shape is one of the distinguishing characters of a bird's eye: the figure (Fig. 2) will give a better idea of it than any description. It represents a vertical section through the middle of an eye in profile, and shows nearly all the structures and organs that can be demonstrated in the ball. Before making use of it, however, the reader must be reminded of the two following points: First, the distinctness of the several membranes forming the ball is greatly exaggerated; for otherwise the different membranes could not be represented as such. Secondly, the ciliary processes, optic nerve, and marsupium, do not fall wholly within the line of a vertical section; they lie curving obliquely against the inside of the walls of the hollow spheroid. But no idea whatever

could be gained of them, were they merely represented at the isolated points where they cross the vertical plane; and they are therefore introduced somewhat artificially. The sacrifice of theoretical accuracy is more than compensated for by increased perspicuity.

Recollecting that the "eyeball"—as we shall continue to call it for convenience sake—is filled with fluid that presses equally in every direction, we cannot at first make out how its peculiar shape is maintained. But the reason why the ball does not assume a spherical shape really is plain enough when we come to dissect its coats. They are partly *bony*. They are splinted, as it were, with the bones (*h*, *h*) that are packed alongside each other all around the circumference of one part of the ball.

Fig. 2.*



The large discoidal segment of a bird's eye is mostly made up of a membrane called the *sclerotic*, from its hard, dense structure. It is a thick, strong, tough membrane, of a glistening livid, or grayish blue color. Three sclerotic coats or layers, differing from each other a little in texture, may be demonstrated by careful dissection, though on super-

*Fig. 2. Vertical antero-posterior section through middle of eyeball. *a*, optic nerve; *b*, sclerotic, outer coat; *c*, sclerotic, middle and inner coats; *d*, choroid; *e*, hyaloid; *f*, marsupium; *g*, cornea; *h*, *h*, bony plates between layers of sclerotic; *i*, *i*, corrugations of choroid, forming the ciliary processes; *k*, *k*, canal of Petit; *l*, *l*, iris; *m*, anterior chamber; *n*, capsule of lens; *o*, lens; *p*, posterior chamber. Neither the retina, nor the peculiar sheathing of the optic nerve, is shown. The nerve, the marsupium, and the ciliary processes, do not wholly fall within a vertical section through the middle of the eye, and cannot be represented in this figure except artificially.

ficial examination the sclerotic presents itself as a single homogeneous tissue. In the figure (*b*) is the outer coat, and (*c*) the middle and inner ones combined. The osseous plates just mentioned lie between the outer and middle sclerotic coats, anterior to the greatest circumference of the eyeball, and nearly or quite extend from the rim of the disk to the edge of the central anterior transparent part of the ball—the *cornea*. They are fifteen or twenty in number, of an oblong, quadrate shape, broader behind, tapering toward the cornea, and so disposed as to form a complete bony circlet around the latter. Collectively, they enjoy some little motion, their anterior margins advancing and receding with the varying convexity of the cornea; but they cannot individually wabble, being firmly bound to each other by the continuation of the sclerotic coats between them.

The *cornea* (*g*) is the thin transparent membrane in front that the bird looks through. It forms the anterior part of the wall of the eye, and is, in one sense, a continuation of the sclerotic; but its texture is very different from that of the latter. It is the prominent convex part of the eye,—the hemisphere of the small globe that has been already mentioned. Its structure offers nothing peculiar, being essentially the same as in mammals; but its shape is remarkable. Always very convex, it is sometimes still more protuberant, being elongated into a sort of cylinder, with a hemispherical top. This tubulation is very great, for example, in the nocturnal birds of prey (Owls, *Strigidæ*). The alteration of shape that the cornea is capable of is next most singular, as will be explained when we come to speak of the powers of the eye as a whole. It is sufficient here to bear in mind the unusual shape of the cornea, and its power of increasing and diminishing its convexity.

The sclerotic coat is lined inside with a membrane of very different tissue—the *choroid* (*d*). While the former is tough and fibrous, with comparatively few blood-vessels, the latter is more loosely woven of cellular tissue, replete with

interlacing blood-vessels, and painted pitch-black all over. The deposit of pigmentary or black coloring matter is very heavy, and serves to absorb those rays of light not needed in vision. The choroid membrane lines all the inside of the eye as far forward as the edges of the bony plates, where it splits into two layers. The *inner* of these turns away from the wall of the ball, towards the axis or middle line of the eye, and in so doing becomes gathered in plicæ, or folds, much as the top of a bag is wrinkled by pulling the string. These radiating folds come from all around, to collect together upon the rim of the crystalline lens (*o*), or rather of the delicate capsule (*n*) that encloses the lens, and adhere there. Their terminations form what are called the *ciliary processes* (*i*, *i*). The *outer* layer also curls away from the sclerotic, and starts to go transversely across the eyeball, but ends at once in the iris.

The *iris* (*l*, *l*) is the most exquisitely beautiful structure in a bird's eye. It is the many-colored curtain that hangs vertically between the two apartments of the eye. It is the highly ornamented framework of the window of the eye, uniting the offices of sash and blind. The crystalline lens is suspended in the round hole punched in the centre of the iris. Viewed in front, from the outside, the iris appears as a colored circular band around the pupil. It seems to lie directly on the surface. But this is not so, for the cornea and its humors are between us and it. It is like the dial-plate of a watch, that we look straight at without noticing the crystal that is interposed. The central aperture through which come the shafts that the hands are fastened to, may be likened to the pupil. Everybody knows what the "pupil" is, in a vague way. It is the round black spot inside the colored rim of the iris; but few understand what the spot is. The difficulty is, that the pupil is regarded as a material thing—a tissue, structure, or organ—when it is not. It is the absence of matter. The round black spot called the pupil is not a "thing;" it is a hole in a thing,—the hole in

the iris through which we look (the transparent crystalline lens offering no obstruction to our view) directly into and across the posterior chamber of the eye, and see the black pigment on the choroid behind. Albino animals have pink eyes, because the coloring matter of the choroid is wanting, and the hue of the blood in its numerous fine vessels appears. And even if we look into a normal eye with the ophthalmoscope, we have a reddish instead of a black field of vision. The pupil takes its name from a very pretty conceit. On looking straight at it, our image is reflected to us, only so diminished that we are transformed into pigmies. We find an expression of the same thing in other languages beside our own. In Spanish, the liliputian photograph is called "niñacita del ojo;" which means "little eye-baby."

But to return from this digression to the iris, which has been all the time nervously quivering at our neglect. It is essentially similar in structure to the choroid, being a delicate tissue of fibres and vessels interlacing in every direction; but it has, in addition, a structure that is regarded as muscular. The iridian muscles are mainly disposed in two ways; there is a circular set running around, and a radiating set that pass across from the inner to the outer border. By means of these, which are mutually antagonistic, the iris is contracted and expanded, and its aperture—the pupil—correspondingly varied in size. In mammals, the movement of the iris appears to be automatic, and to depend upon the stimulus of light; and they are not so great, as a general rule, as in birds. In the latter, they are extraordinary, not only in degree, but in the rapidity with which they may be executed. Although birds' irides respond primarily, and perhaps chiefly, to the action of light, their movements seem to be partly, at least, subject to the will, and therefore voluntary. These conditions of mobility in the iris relate directly to such exigencies as, for examples, the owl meets with in the daytime, or the eagle encounters in his flight towards the sun.

The iris of birds is copiously supplied with coloring matter; the tints vary with different species, and are often extremely brilliant. Some shade of brown is, perhaps, the commonest color. Yellow is very common; red is often seen; blue and green are more rarely met with. The eyes of Cormorants are of the latter color. Sometimes the iris is blackish, or black, like the choroid; and it is frequently pure white, as in the instance of one of our common birds, the White-eyed Greenlet (*Vireo Novæboracensis*).

The *crystalline lens* (*o*) is a transparent bi-convex disk, just like a common magnifying glass. It apparently hangs on the iris like a looking-glass in its frame, but is really set a little further back. In birds, it is rather flatter, especially behind, and also softer in consistency, than in some other classes. It is enclosed in a very delicate transparent membrane, its *capsule* (*n*), which is in turn set in between two layers of a membrane, called "hyaline," to be presently described. Where the two hyaloid layers separate around the rim of the capsule, to form its case, a small space is left, that makes a circular tube all around, called the *canal of Petit* (*k*, *k*). The lens is stationary as far as the axis of vision is concerned; but is capable of being moved a little forwards and backwards, by the pressure of the humors of the eye, which is produced by the coöperative action of certain muscular and vascular structures, as we shall see before we get through. This movement adjusts the focus for vision, exactly as it is adjusted in a telescope, for instance, by lengthening or shortening the tube.

We can understand, now, that the eyeball is divided into two compartments, or "chambers," as they are called, by the inward reflection of the two choroid coats, the hyaloid, the iris, and the lens, which together form a vertical wall. Both of these chambers are filled with fluid, of different density and consistence in each. That in the anterior division is thin and watery, and therefore called the "aqueous humor;" that in the posterior one is more dense and glassy, and is for

this reason known as the "vitreous humor." There is much less aqueous than vitreous, because the anterior chamber is much the smaller of the two; but birds have more of the former, compared with the quantity of the latter, than mammals, because the size and convexity of the cornea is relatively greater. The aqueous humor is enclosed in a very delicate simple membrane, that cannot be demonstrated without difficulty. The vitreous is contained in a more palpable, as well as complex membrane—the *hyaloid* (*e*)—which, besides lining the interior of all the back part of the eye, and enclosing the lens as already described, sends thin laminæ, or layers, all through the vitreous humor, forming partitions that serve to steady the glassy waters.

We may next turn our attention to the optic nerve (*a*) that presents itself in the all-important character of the "soul of the eye." It has many peculiarities in birds; among them one that constitutes the most characteristic feature of the eye of these creatures. In mammals, as a general rule, the nerve is a smooth cylinder that comes straight to the sclerotic, near the middle behind, penetrates straight through the coats of the eyeball, and then spreads out on all sides to form a disk on the inside of the back of the eye. This circular saucer-like expansion is the *retina*—the sensitive nervous plate, or mirror, upon which images of things viewed are photographed, to be transmitted along the nerve to the brain, and there "perceived." Suppose the optic nerve to be an umbrella-handle, the retina would then be the umbrella, blown inside out by the wind. In birds the nerve acts very differently. In the first place, though it is cylindrical, it is not smooth; it has lengthwise folds and ridges. It is like a fluted column. It comes obliquely towards the eye, which it strikes at a point eccentric from the axis of the ball; and then, instead of at once piercing all the sclerotic coats, and expanding into a concavo-convex disk, it tapers gradually to a fine point. This elongated extremity runs still obliquely, downwards and forwards, in a deep groove in the sclerotic, that

would be a perfect sheath were it not split lengthwise. Through this slit, and through a corresponding one in the choroid membrane, a fold or fluting of the nerve rises up, finally attaining the inside of the eye. The retina spreads out from all along the sides and extremities of this fold.

Only one other structure remains to be described—the crowning anatomical peculiarity of a bird's eye. This is the *marsupium*, or *pecten* (*f*). Though attached at one end to the optic nerve, it is not a part of the nerve at all, nor composed of nervous tissue. It is a very vascular membrane, most like the choroid in texture, and likewise painted black. When fully extended, it is seen to be of an oblong or rectangular shape; when lying naturally *in situ*, it is much drawn up, and its sides are transversely wrinkled or plicated. It is suspended in the vitreous humor, running obliquely forwards a great part, or the whole of the way, from the end of the optic nerve to the crystalline lens. In the former case it appears attached anteriorly to some of the laminæ of the hyaline; in the latter to the capsule of the lens. Behind, it is always fastened to the optic nerve. It is called the "marsupium," because it does not in the least resemble a purse or pouch; and the "pecten" because it does not look anything like a comb. Anatomists have not agreed upon what to consider as the function of this organ, nor upon the *quo modo* of its operation. Some have thought that it absorbs the superfluous rays of light that must often enter the eye, because it is blackened with pigment. One who adhered to this belief went further, considering that, from its eccentric position, it absorbs mainly oblique rays, which being taken away, objects placed in direct rays may be more plainly perceived. Some, again, have regarded it, in consequence of its vascular structure, as the organ that secretes, or aids the choroid in secreting the vitreous humor; an additional apparatus being needed for the elaboration of this fluid, because it is used up so fast in the rapid and incessant movements of the eye. But the theory now generally ac-

cepted differs from all of these hypotheses, and makes out the marsupium to be an "erectile" organ. Although no muscular fibres have been shown to exist in it, yet it is probably capable of expansion and contraction much as if it were muscular. It is a highly vascular structure, as we have seen; and the increased or diminished turgidity of its numerous blood-vessels* would, of course, alter its dimensions. If it occupies a variable space in the vitreous humor, it must affect the position of the lens, and by this means change the focus of the eye. This seems to be the most satisfactory explanation, both of the design of the marsupium, and of the mode in which its design is carried out. In this view, the organ is marshalled with several others that we know contribute to the greatest physiological phenomenon of a bird's eye,—the rapid adjustment of focus.

As anatomists, we have examined the structure, and position, and appearance of the organs that make up a bird's eye. But our study would be to little purpose if it ended here with an inspection of dead tissues. We have seen some curious things that, perhaps, have afforded us gratification, which is well enough as far as it goes; but curiosity is only laudable when, disdaining amusement as an ulterior object, it is contented only with a higher aim,—instruction. We must look, as physiologists, at the operations of the eye, and the mode in which its functions are conducted and accomplished. All that has gone before is merely to prepare us to question intelligently the structures we have examined, and find out how they work.

Eyes are made to see with, of course; but *how* we see with our eyes nobody knows. No one can tell us *how* an

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*It is not apparent, at first sight, whence the marsupium gets its numerous vessels, since it is not attached at all to the vascular membrane of the eye,—the choroid. Professor Owen remarks on this subject: "Branches of the ophthalmic artery, distinct from the vessels of the choroid, and homologous with the *arteria centralis retinæ*, enter the eye between the laminæ of the retina, along the whole extent of the oblique slit (in the sclerotic and choroid), and immediately penetrate the folds of the marsupial membrane, upon which they form delicate ramifications." (Anatomy of Vertebrates, Vol. II, p. 139.)

image formed on the retina is conveyed to the brain, and transformed into a mental perception, capable of being thought about. This is inscrutable; it is here the part of wisdom to confess ignorance, and acknowledge bounds that human reason cannot overstep. Nor have we need here to go into the general optical laws applicable to vision; they are well known, and moreover relate no more to a bird's eye than to that of any other animal. What we want is to find out the *meaning* of the structural peculiarities by which a bird's eye differs from other eyes. What is the reason and the purpose of the three eyelids? of the shape of the ball? of the very abundant aqueous humor? of the movable lens? of the marsupium? the tapering nerve? What special relation do these and other features bear to the sense of sight in birds? In other words, why must a bird have just this sort of an eye to be able to see perfectly? Some of these questions can be satisfactorily answered; others not. Some we have already replied to as they arose in our mind involuntarily during our dissection. Thus the third lid gives a subdued light, without excluding light altogether; and also protects the eye, which could not be otherwise protected without closure of its outer opaque lids, and loss of sight altogether. The very convex and highly refractive cornea doubtless has some relation to a bird's ability to see straight ahead, though its eyes look directly sidewise.

Perhaps no reason has been assigned for the singular course and termination of the optic nerve. These have possibly no special optical relations; the cause may lie simply in the relative situations of the brain and eye, which are such, that the nerve would have to change its course abruptly to pierce directly through the sclerotic. We cannot see through a crooked tube, any more than we can shoot round a corner. Nerves are the railroads of thought. A train of thought might run off the track if the curves and grades were not easy. I believe that we find comparatively few instances of abrupt angles in the course of nerves. If

we consider the marsupium as an erectile organ, we are not content to understand how it erects itself, and what it accomplishes by erection; we want to know why it is necessary or desirable that it should do what it does.

Putting together all that we do know of the operation of a bird's eye; and from this inferring some things that we do not know, we are irresistably led to the conclusion, that all the essential peculiarities of a bird's eye conspire to produce what we just now called its greatest physiological phenomenon—*instantaneous unerring adjustment of focus.*

Study of the habits of birds makes the necessity of some such faculty as this as evident as the fact of its existence. This admirable provision relates in the most direct manner possible to the rapid movements of birds in the air. As they dash onward in their airy course, the eye accommodates itself, if not with the speed of thought, at least with the speed of flight, to ever-varying distances, and surrounding objects, be they far or near, all alike rush into focus. With our own eyes, we see at once a book before us, and a large object in the distance. Push the book away by degrees; the letters run into words, words into lines, lines into paragraphs, paragraphs into a solid page of dark, surrounded by a white border; then the edges of the cover gain a film, the outlines soften, the thing becomes a spot, and finally disappears. If a bird were in our place, it would still see letters long after they had disappeared from our view. Its eye would change in shape, and the structures within alter in position, as the book moved off, slowly, gradually, constantly, till the limit of its power was reached; and this limit it need not be said, far exceeds ours. Walk towards the large object now indistinct in the distance. How long we are in approaching it: how very slowly it takes form as we advance, until it stands forth clearly in view! Let a wild duck fly at the rate of ninety miles an hour, towards the same object. How rapid must be the adjustment of its eyes compared with ours! But these are among the

moderate exhibitions of a bird's visual powers. Watch a Humming-bird: it darts away so swiftly that our eyes cannot follow it, and settles, light as a feather, upon a twig. We do not know how far off it discovered the twig; but, at whatever distance it was first brought into focus, the Humming-bird's eye adjusted itself during the fraction of a second that the bird was flying; and the twig was in focus at the instant the bird alighted upon it. Were we to move with the same velocity, our eyes would fail us; they could not accommodate themselves quick enough. See a Sparrow-hawk dash through a thick clump of bushes in headlong pursuit of its prey. Think you it rushes blindly, taking the chances of escaping the close-set obstacles in its way? It sees each stake and branch as it comes on, and avoids them all. Had we a Sparrow-hawk's power of flight we could not follow him for want of his powers of vision.

Observe an eagle circling in the air. He is soaring aloft higher and higher, till he becomes, to us, but a speck against the blue expanse. As he turns towards the sun, a signal is made, and quick as thought obedient servants obey the summons. The nictitating membrane, asleep in its corner, starts up and spreads over the cornea in an instant: the quivering iris, ever on the alert, enfolds the crystalline lens in a close embrace; and the tranquility of the retina is undisturbed. As he turns away, the enemy no longer harasses, and the guards retire. Now the great bird prepares to scan the ground below. His eye lies loosely in its socket; the muscles relax; the marsupium lies torpid; the lens falls back; the cornea sinks; the waters retire; all are quiet. The retina alone glows and thrills with excitement. He is now far-sighted; he descries an object on the earth smaller than himself, even from this vast height; and makes ready for the fearful plunge. He poises a moment; the word is given; as trusty sailors to their posts to save the good ship in a storm, so rush the sentinels of the eye into action. Down he swoops; the muscles tauten, and the waters rush forward;

the cornea feels the pressure within, and starts out; the marsupium stands erect, swelling and bristling all over, and the lens leaps forward, while the iris flaunts the flag of battle. Guided by such an instrument as this, the bird comes down with unerring aim upon his quarry; he seizes it in his talons; and now, become near sighted, well can he see to perform the bloody work before him.

There is, perhaps, as much to be seen in a view of a bird's eye, as ever lies within the bounds of a "bird's-eye view."

HABITS OF THE BURROWING OWL OF CALIFORNIA.

BY DR. C. S. CANFIELD.*

I WISH to state a few facts about the Burrowing Owl (*Athene cunicularia* Molina) that lives in California. I had almost constantly for four years opportunities of observing the habits of this little owl, which is really one of the most notable features in the natural history of California. A colony of these owls lived within one hundred yards of my cabin while I passed a frontier life; and they were very common everywhere in that vicinity. I have seen them every day for years, hundreds and perhaps thousands of them in all. Where I have seen them, they always live in the deserted or unoccupied burrows of the Ground Squirrel (*Spermophilus Beecheyi*). I came to the conclusion that they were able to drive out the Spermophiles from their habitations, but I am not certain of the fact. It is true that there were, in that region, always a large number of unoccupied burrows wherever there was a colony of Spermophiles; so that there was no lack of unoccupied habitations for the owls to take possession of. But I have noticed that wherever there was a large number of the owls, very few or no Sper-

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